

Mask blank and method of fabricating phase shift mask from the same

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Abstract

A mask blank includes a transparent substrate, a light shield layer formed on the upper surface of the transparent substrate, and a multi-functional protective layer formed on the light shield layer. To make a phase shift mask from the blank, the protective layer is patterned, and the light shield layer is etched using the protective layer pattern as an etch mask. The phase shift region is formed by etching a groove in the second region of the substrate while the protective layer pattern protects the light shield layer. Therefore, undesirable residue is prevented from forming at the bottom of the groove constituting the phase shift region. The method also entails patterning a photosensitive layer on the protective layer, and patterning the protective layer by using the patterned photosensitive layer as a mask. In this case, the structure is cleaned so that no residue remains on the exposed portions of the light shield layer.

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Description

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a phase shift mask used to fabricate semiconductor devices, and to a method of fabricating a phase shift mask from a mask blank. More particularly, the present invention relates to a mask blank and to a method of fabricating an alternating phase shift mask from the mask blank.

[0004] 2. Description of the Related Art

[0005] The degree of integration of a semiconductor device is proportional to the resolution power of exposure equipment used to fabricate the semiconductor device. Accordingly, research has been conducted with an aim towards increasing the resolution power of semiconductor exposure equipment. The optical source of the exposure equipment is an important factor dictating the resolution power of the equipment. Therefore, much of the above-mentioned research centers around exposure equipment having an optical source which emits light of a short wavelength.

[0006] The resolution power of the exposure equipment must be in accordance with the degree of integration of the semiconductor devices being fabricated. To avoid the enormous expense that would be associated with providing new equipment for fabricating more highly integrated devices, a method of increasing the resolution power of conventional exposure equipment is used.

[0007] The method can be accomplished by using a phase shift mask, for example, an alternating phase shift mask.

[0008] A conventional method of fabricating an alternating phase shift mask, and problems thereof will now be described with reference to FIGS. 1 through 7. Referring first to FIG. 1, a chromium layer 12 is formed on a transparent substrate 10, and photosensitive film patterns 14 which expose predetermined areas on the chromium layer 12 are formed on the chromium layer 12. The entire surface of the chromium layer 12 is etched using the photosensitive patterns 14 as an etch mask. Then, the photosensitive film patterns 14

are removed.

[0009] Referring to FIG. 2, chromium layer patterns 12a are formed on the transparent substrate 10 by the etching. Also, the exposed areas of the chromium layer 12 are etched away, thereby exposing the surface 13 of the transparent substrate 10 at a first area A1 and a second area A2. The first area A1 is a phase non-shift area, and the second area A2 will eventually constitute a phase shift area.

[0010] Referring to FIG. 3, photosensitive film patterns 16 are formed on the resultant structure on which the chromium layer patterns 12a are formed, so that the first area A1 of the transparent substrate 10 and the chromium layer patterns 12a are covered while the second area A2 is exposed.

[0011] Referring to FIG. 4, a groove 18 is formed in the transparent substrate 10 at the second area A2, using the photosensitive film patterns 16 as an etch mask. In this way, the phase shift area is formed on the transparent substrate 10. The formation of the groove 18 makes the second area A2 of the transparent substrate 10 thinner than the first area A1.

[0012] The photosensitive film patterns 16 are removed, resulting in a phase shift mask including the first area A1 and the second area A2 as shown in FIG. 5.

[0013] However, according to the conventional method of fabricating a phase shift mask as described above, material is left on the surface of the transparent substrate 10 and at the bottom of the groove 18 in the processes of forming the chromium layer patterns 12a and forming the groove 18 in the transparent substrate 10.

[0014] For example, residue from a previous step, e.g., the step of forming the photosensitive film patterns 14, can remain on the exposed surfaces of the chromium layer 12. The residue obstructs the etching of the exposed portions of the chromium layer 12. The residue in fact acts as an etching mask. Therefore, although the surfaces 13 and 13a of the transparent substrate 10 are exposed by removing the exposed portions of the chromium layer 12, a defect (not shown), that is, unwanted material, including chromium, is formed on the exposed surfaces 13 and 13a of the transparent substrate 10. The defect is repaired by a laser. In this process, the chromium absorbs the laser, is melted, and is sublimated, whereby it is removed. Simultaneously, heat absorbed from the laser is transmitted to the portion of the transparent substrate 10 lying beneath the chromium. Consequently, the exposed surfaces 13 and 13a of the transparent substrate 10 are fused and then solidified. The change in physical state makes the material of the transparent substrate 10 in the neighborhood of the exposed surfaces 13 and 13a different from that of other portions of the transparent substrate 10. Thus, what often happens is that material of the exposed portions 13 and 13a of the transparent substrate 10 does not react to an etch gas or is slow to react thereto in the process of forming the groove 18 in the transparent substrate 10. As a result, a portion 20 (FIG. 6) of the substrate 10 remains unetched or only partially etched after the groove 18 is completely formed. The portion 20 is a defect because it changes the phase of light passing through the phase shift area A2. Also, light is diffracted at the sides of the portion 20 of the substrate, thus adversely affecting the formation of patterns using the mask.

[0015] Referring to FIG. 7, in the conventional method of fabricating a phase shift mask, a residual layer 22 is also formed at the phase shift area A2 as a result of the process of etching the groove 18 in the substrate 10. The material of the residual layer 22 is a compound of chromium (Cr) and fluorine (F), formed by the reaction of the etch gas, which is used to form the groove 18, with the chromium layer patterns 12a. The residual layer 22 inhibits the transmittance of light incident upon the second region A2 and abnormally changes the phase of light passing therethrough. Also, the residual layer 22 is formed prior to the completion of the groove 18 and impedes the etching of the substrate 10 during the process of forming the groove 18. Accordingly, the residual layer 22 prevents a complete forming of the groove 18.

SUMMARY OF THE INVENTION

[0016] Accordingly, a first object of the present invention is to solve the above-described problems by providing a mask blank by which defects can be prevented from being formed on a substrate during a process of fabricating a phase shift mask, and in particular, an alternating phase shift mask, from the mask blank.

[0017] To achieve the first object, the present invention provides a mask blank comprising a substrate which is transparent to incident light (exposure light of a given wavelength), a light shield layer formed on the entire surface of the transparent substrate, and a protective layer formed on the entire surface of the light shield layer. The protective layer, among other things, protects the light shield layer from etch gas during a process of etching the substrate to form a phase shift region. The light shield layer is prevented by the protective layer from reacting with the etch gas, whereby the groove in the substrate formed as a result of the etching is free of residue. The protective layer itself produces no residue by-product when exposed to the etch gas.

[0018] In this respect, the protective layer can be formed of a material which adheres well to the light shield layer and evaporates in the presence of the etch gas. For instance, when the light shield layer comprises chromium, and the etch gas contains fluorine, the protective layer can be molybdenum silicon oxynitride

(MoSiON).

[0019] A second object of the present invention is to provide a method of fabricating a phase shift mask, wherein the method prevents undesirable residue from accumulating on the substrate of the mask at the bottom of a groove constituting the phase shift region.

[0020] To achieve the second object, the present invention provides a method of fabricating a phase shift mask comprising the steps of forming a light shield layer on the upper surface of a transparent substrate, forming a protective layer pattern on the light shield layer to expose portions of the light shield layer, etching the exposed portions of the light shield layer using the protective layer pattern as an etch mask to in turn expose first and second regions of the substrate, and forming a phase shift region by etching a groove in the second region of the substrate while the protective layer pattern protects the light shield layer from the etchant.

[0021] Once the first and second regions of the substrate are exposed, the substrate is coated with a photosensitive layer. The photosensitive layer is a photoresist layer for an electron beam (e-beam). The photosensitive layer is patterned to expose the second region. The groove can then be etched in the second region using the photosensitive layer pattern as an etch mask. The etching is controlled until the thickness of the second region of the substrate is reduced to the desired phase shift thickness.

[0022] A marginal part of the protective layer pattern bordering the second region is exposed when the photosensitive layer pattern is formed. The exposed part of the protective layer is also etched while the groove is being formed.

[0023] The etching is an anisotropic dry-etching process preferably using an etch gas of CHF₃, SF₆ or CF₄. The protective layer is formed of a material which evaporates in the presence of the etch gas, such as molybdenum silicon oxynitride (MoSiON).

[0024] A third object of the present invention is to provide a method of fabricating a phase shift mask, wherein the method prevents undesirable residue of a light shield layer from remaining on a region of a substrate from which the light shield layer should have been etched away completely.

[0025] To achieve the third object, the present invention provides a method of fabricating a phase shift mask comprising the steps of sequentially forming a light shield layer and a protective layer over the entire surface of a substrate, coating the entire surface of the protective layer with a layer of photosensitive material, patterning the photosensitive layer, etching the protective layer using the patterned photosensitive layer as an etch mask to expose portions of the light shield layer, removing the patterned photosensitive layer and then cleaning the resultant structure so that no residue remains on the exposed portions of the light shield layer, etching away the exposed portions of the light shield layer using the patterned protective layer as an etch mask to in turn expose first and second regions of the substrate, and forming a phase shift region at the second region of the substrate.

[0026] A charging prevention layer can be formed over the photosensitive layer, and the charging prevention layer and the photosensitive layer can be sequentially patterned using an electron beam. In this case, the etching of the protective layer is carried out using the patterned charging layer and the patterned photosensitive layer collectively as an etch mask, and the patterned charging prevention layer is removed along with the patterned photosensitive layer.

[0027] This method can also be carried out under the particulars summarized above in connection with the second object of the present invention, whereby both of the advantages associated with the prevention of residue from forming at the bottom of the groove in the phase shift region, and of preventing residue from remaining adhered to the exposed portion of the substrate which is to be etched to form a phase shift region, can be realized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The above and other objects, features and advantage of the present invention will become more apparent from the following detailed description of preferred embodiments thereof made with reference to the attached drawings, of which:

[0029] FIGS. 1 through 5 are cross-sectional views illustrating a conventional method of fabricating an alternating phase shift mask;

[0030] FIGS. 6 and 7 are cross-sectional views illustrating defects in an alternating phase shift mask fabricated by the conventional method;

[0031] FIGS. 8 and 9 are cross-sectional views of first and second embodiments of mask blanks, respectively, according to the present invention;

[0032] FIGS. 10 through 15 are cross-sectional views illustrating a first embodiment of a method of fabricating an alternating phase shift mask according to the present invention; and

[0033] FIG. 16, together with FIGS. 12 through 15, illustrates a second embodiment of a method of fabricating an alternating phase shift mask according to the present invention.